
Earth System Science Server (ES3): Local Infrastructure for Earth Science Product Management

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Constraints

- ❑ The Science Information User
 - I want reliable, timely, usable science information products
 - ⇒**Accessibility**
 - ⇒**Accountability**
- ❑ NASA
 - We want all this done by a distributed federation of providers, not just by us.
 - ⇒**Scalability**
- ❑ The Science Information Provider
 - Hey, I'm doing just fine, thanks. Why should I change the way I use computers to do science?
 - ⇒**Transparency**

Research vs. production computing

Research computing is ...

- ❑ Heterogeneous
 - multiple platforms, applications, languages
- ❑ Idiosyncratic
 - researchers typically have highly *customized* computing environments
- ❑ Problem-driven
 - focus on results, not processes

Production computing is ...

- ❑ Robust
 - reliable, not just correct
- ❑ Standardized
 - can easily substitute components for repair, upgrade, etc.
- ❑ Scaleable
 - accommodates steady or increasing demand for product

Principles

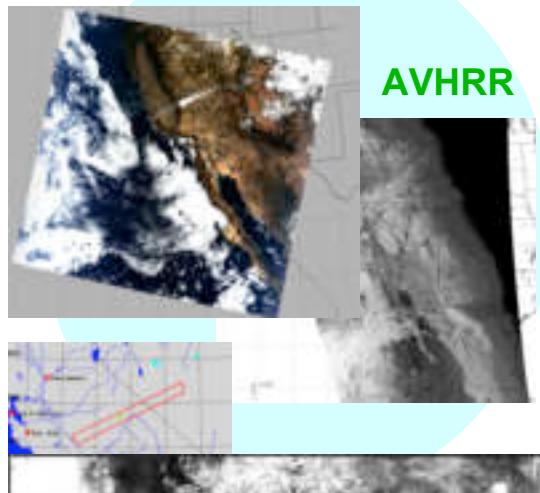
- ❑ Goal
 - Help Earth scientists become information providers in a federated data system
- ❑ Prime Directive
 - Minimal disruption of a working scientist's computational environment
- ❑ Ultimate product
 - Software, system architecture, and procedures for turning Earth science projects into ESIPs

ESSW data lineage tracking

ES³ : Earth System Science Server



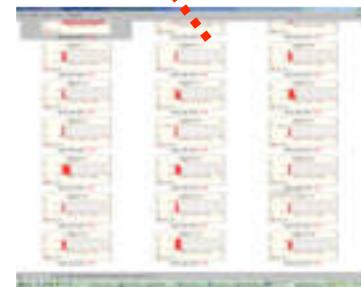
MODIS



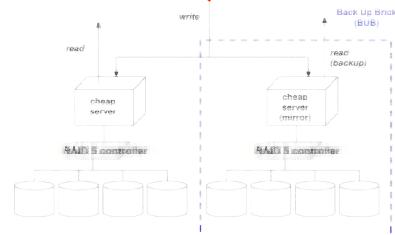
AVHRR



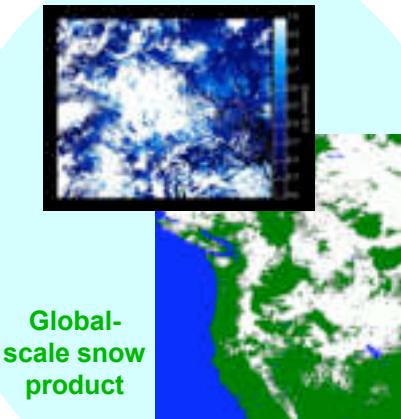
Corona



BUB data storage

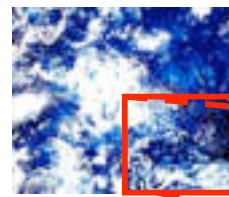


Watershed-scale snow product



Global-scale snow product

MODster



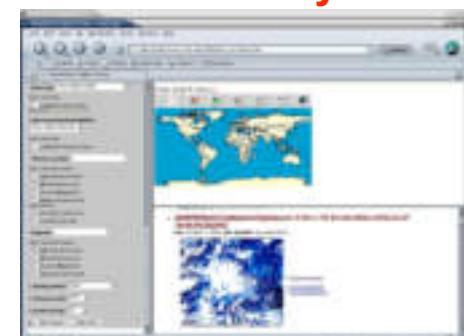
OpenDAP



Microsoft TerraServer



Alexandria Digital Library



STORAGE MANAGEMENT

Back-Up Bricks
(BUBs™)

™ Barely Online Storage Systems, Inc.

Everything Online: Rationale

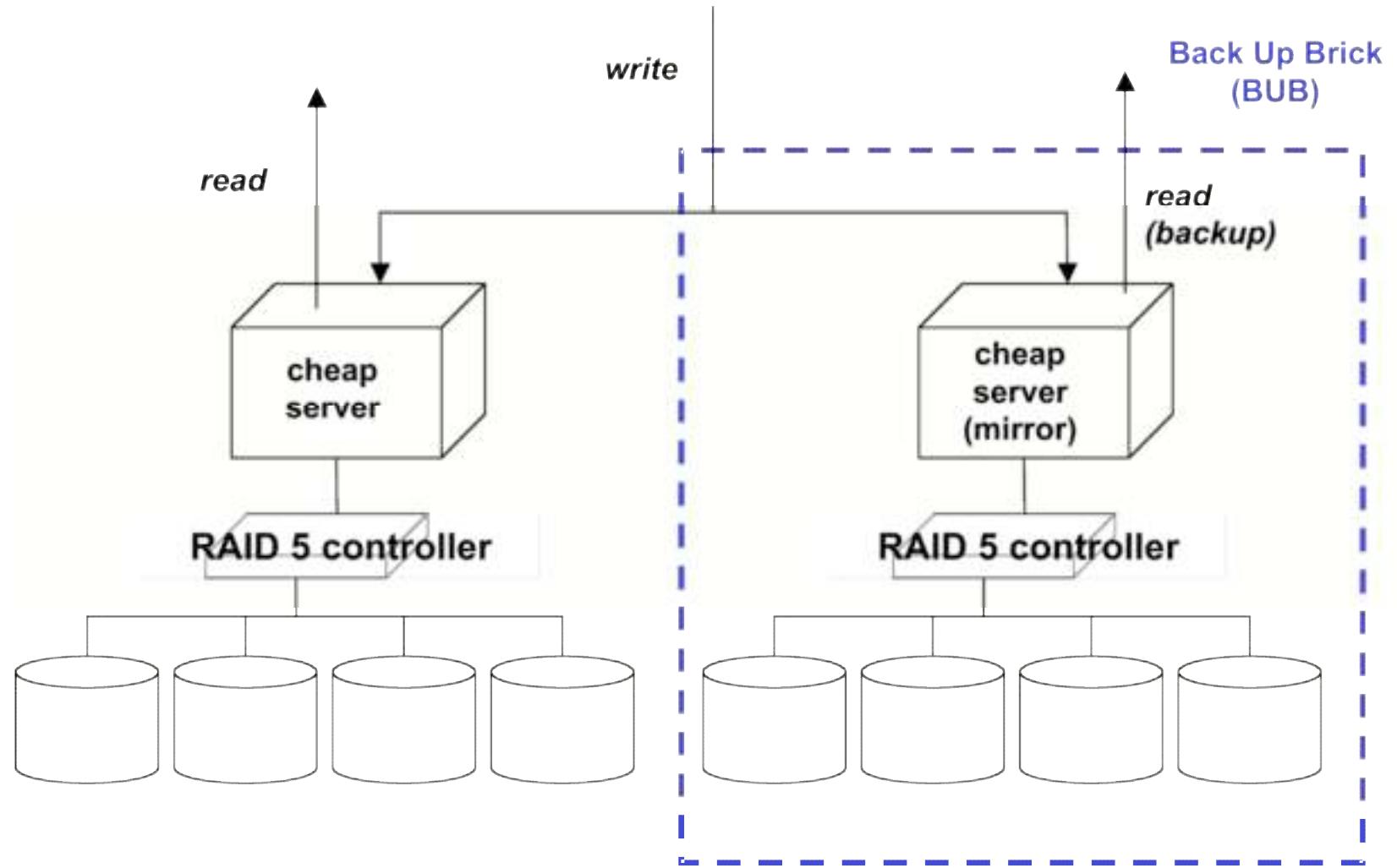
❑ Accessibility

- rapid, electronic delivery
 - Providers can't afford to handle media
 - Users *can* afford high-speed network connections
 - ◆ E.g. cable modem: 1 GB/hr @ \$40/mo → ~\$0.06/GB
- ♣ custom (re-)processing
 - Not practical if everybody waiting on tape drives

❑ Practicality

- Costs are plummeting
 - 1 GB < \$1
- Reliability is increasing
 - RAID = high availability + large filesystems
 - geoplexing

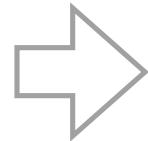
BUBs: \$3K / TB (May 2004)



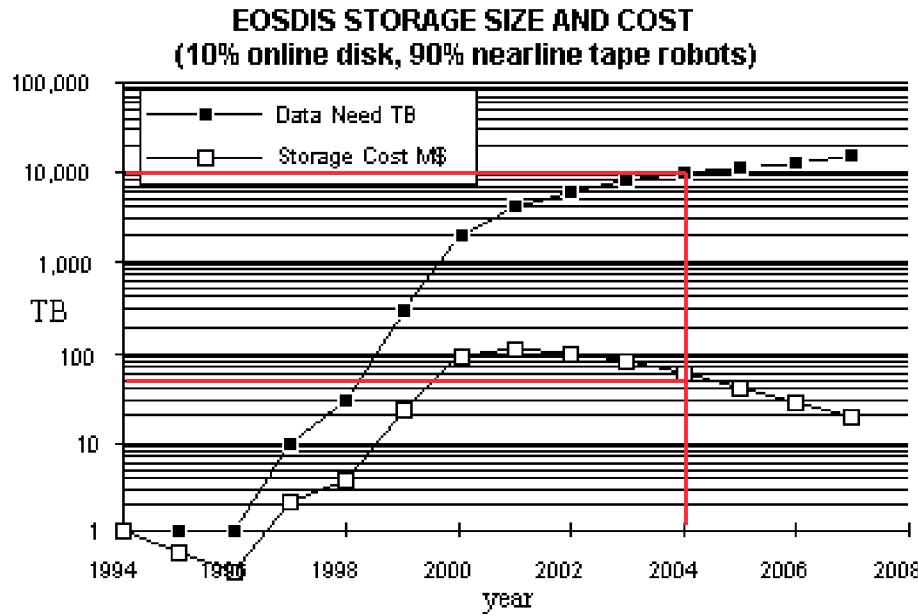
Before...



Earth System Science Server ...After



It's Even Better Than We Thought...



http://research.microsoft.com/~gray/EOS_DIS

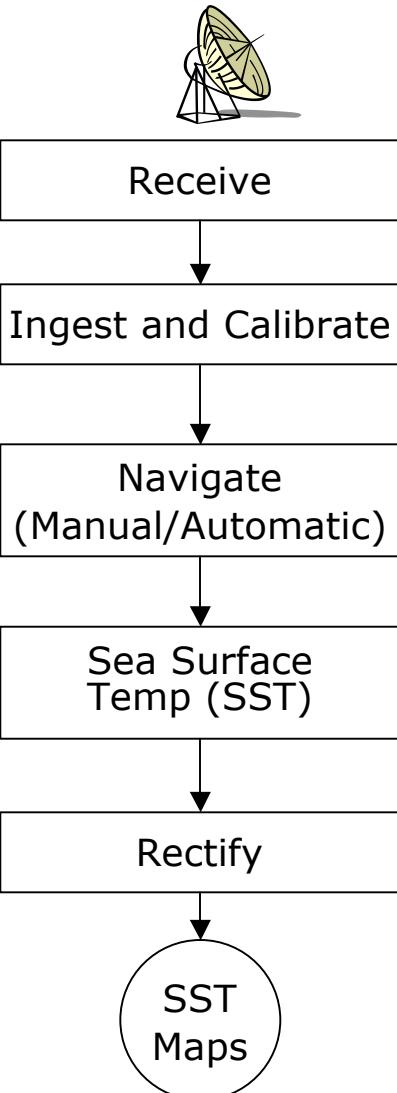
- 1995 prediction
 - 10 petabytes:
 1 PB disk
 + 9 PB tape robots
 = \$50 million
- 2004 reality
 - 10 petabytes:
 20 PB disk
 = \$20 million
- NB:
 - 10% -> 100% online
 - Cost /= 2

METADATA MANAGEMENT

Earth System Science Workbench
(ESSW)

Using Existing Science Applications

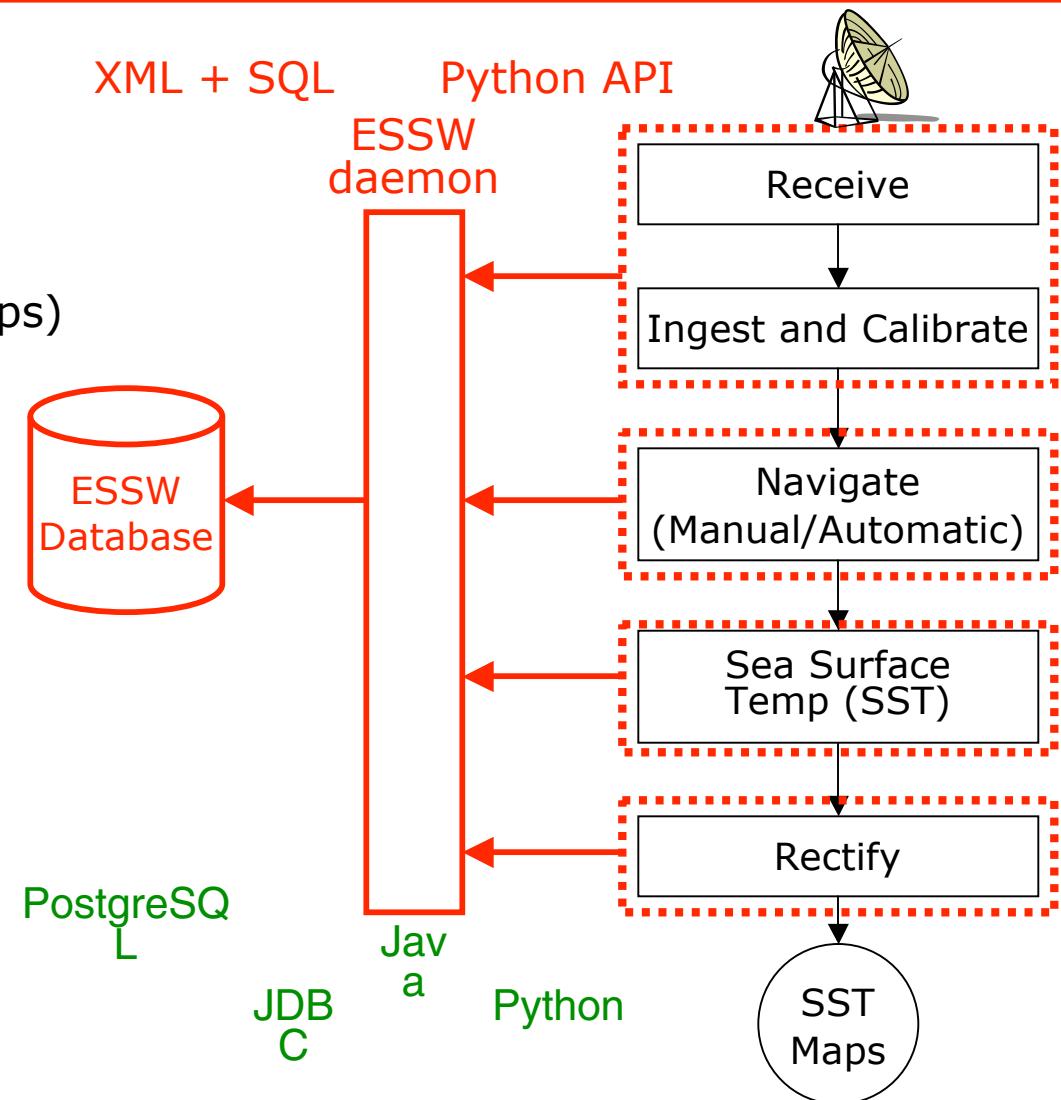
- ❑ No “standard” Earth science computing environment
 - commercial packages (ArcInfo, MATLAB, ...)
 - public packages/models (MM5, MODTRAN, ...)
 - locally-developed codes
 - arbitrary combinations of ↑
- ❑ Example: SST from AVHRR → → →
 - commercial, standalone programs
 - parameters highly customized for UCSB
- ❑ How do we get these programs to
 - communicate
 - cooperatewith ESSW, without rewriting them?



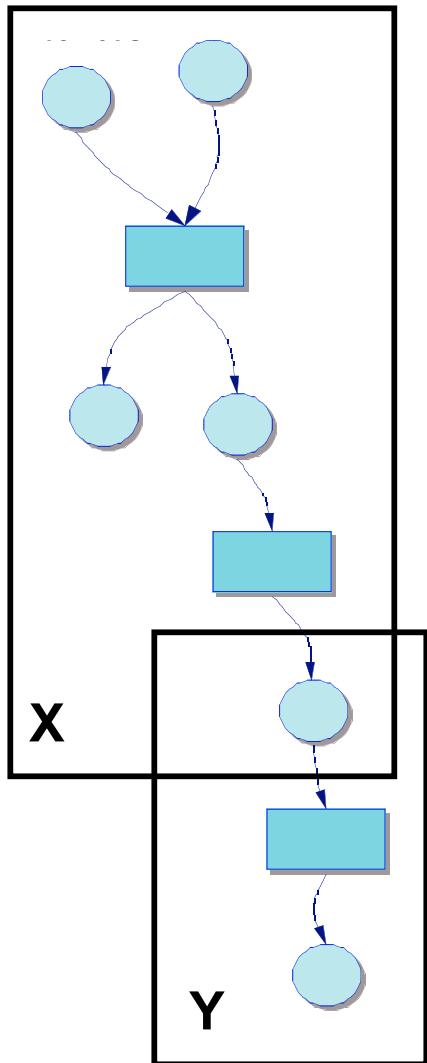
Wrap Your App: Scripts Talk to ESSW

- ❑ No *changes*, just *additions*

- Wrapper scripts
 - Make program (groups) look like ESSW experiments
- ESSW daemon
 - Converts wrapper output to database input
- ESSW database
 - Stores converted wrapper output



Lineage Metadata: Parent/Child Pairs

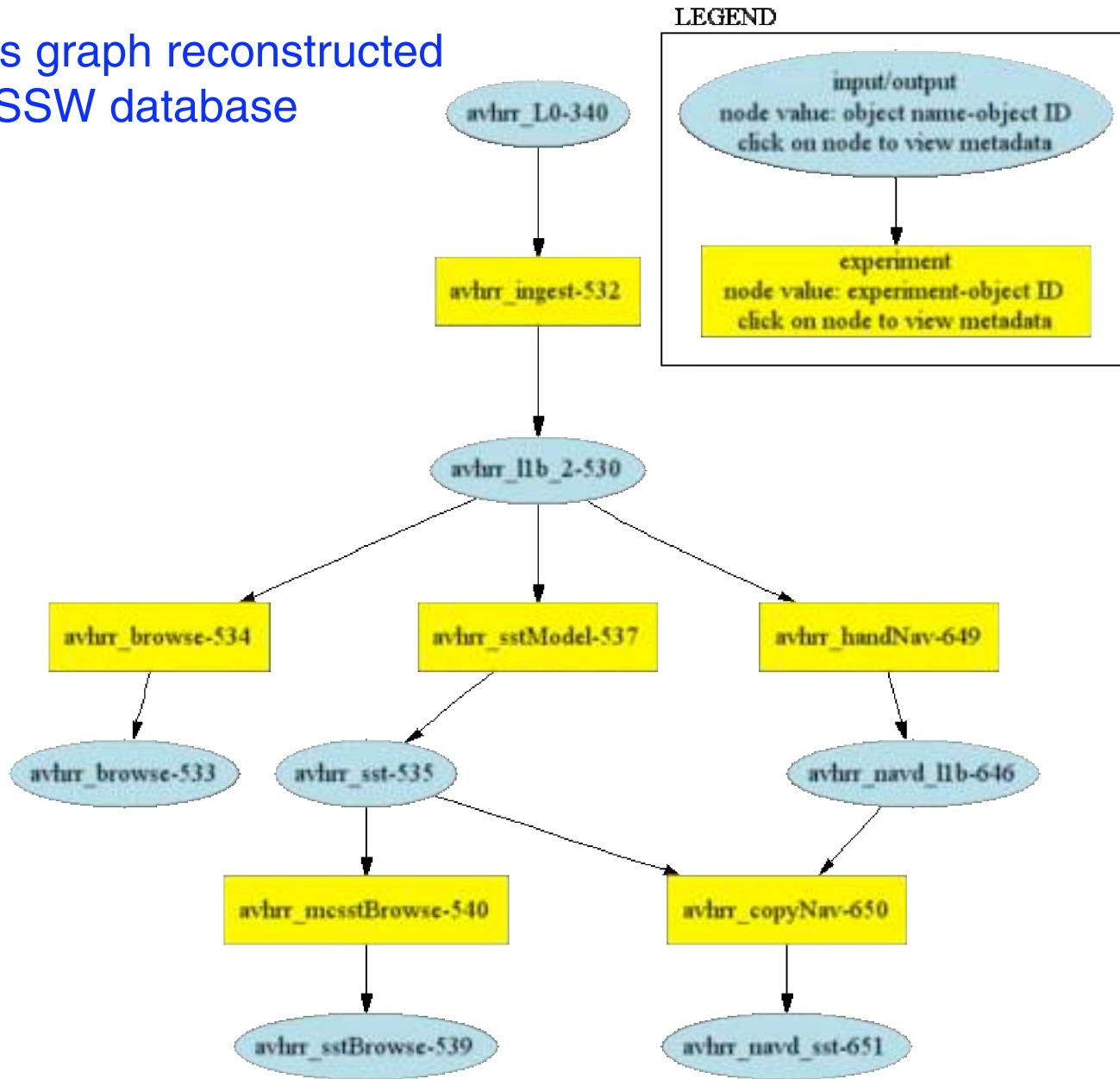


Parent	Child
1	a
2	a
a	3
a	4
4	b
b	5
5	c
c	6

Group 1:
workflow invocation X

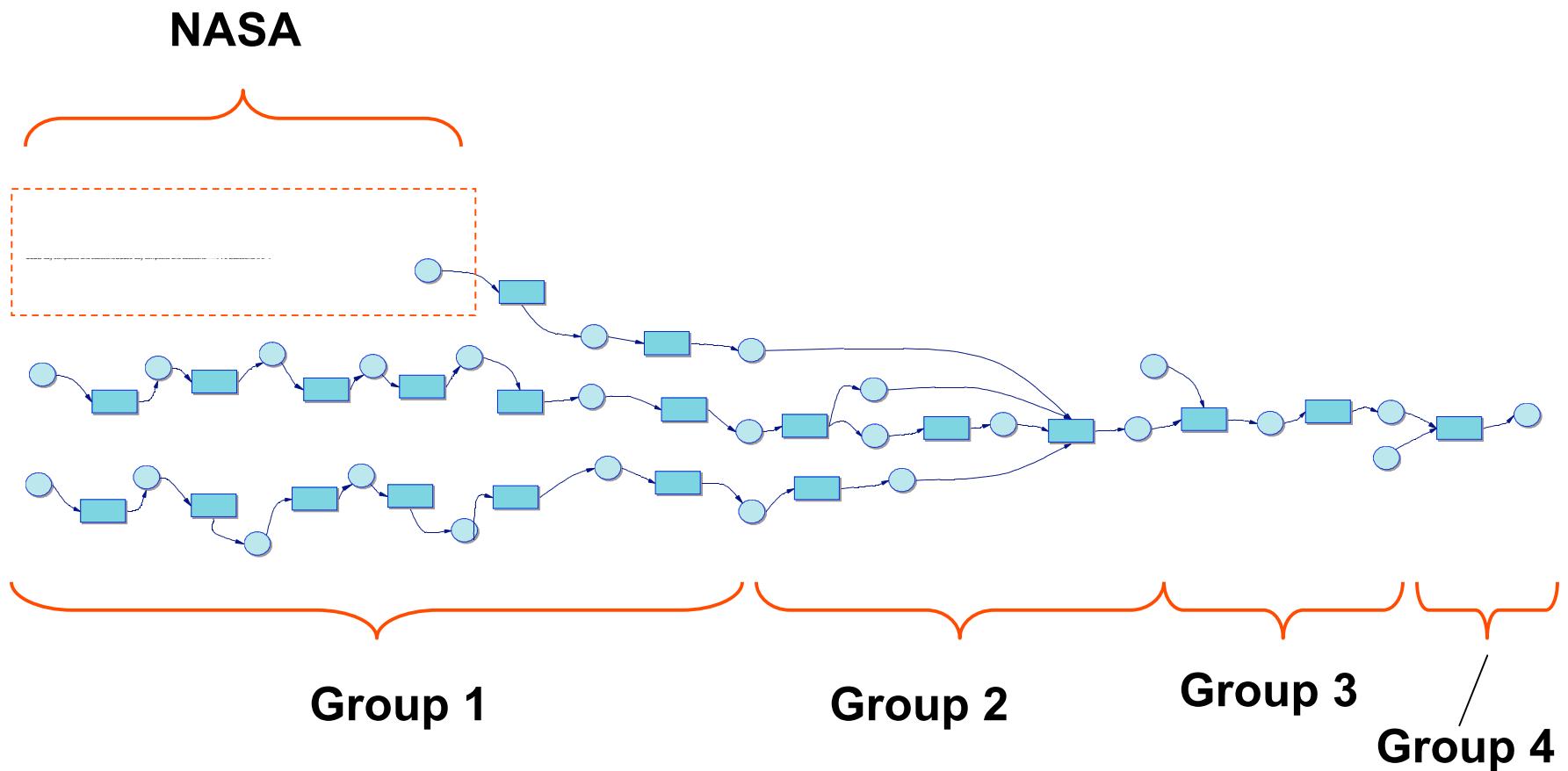
Group 2:
workflow invocation Y

Process graph reconstructed from ESSW database

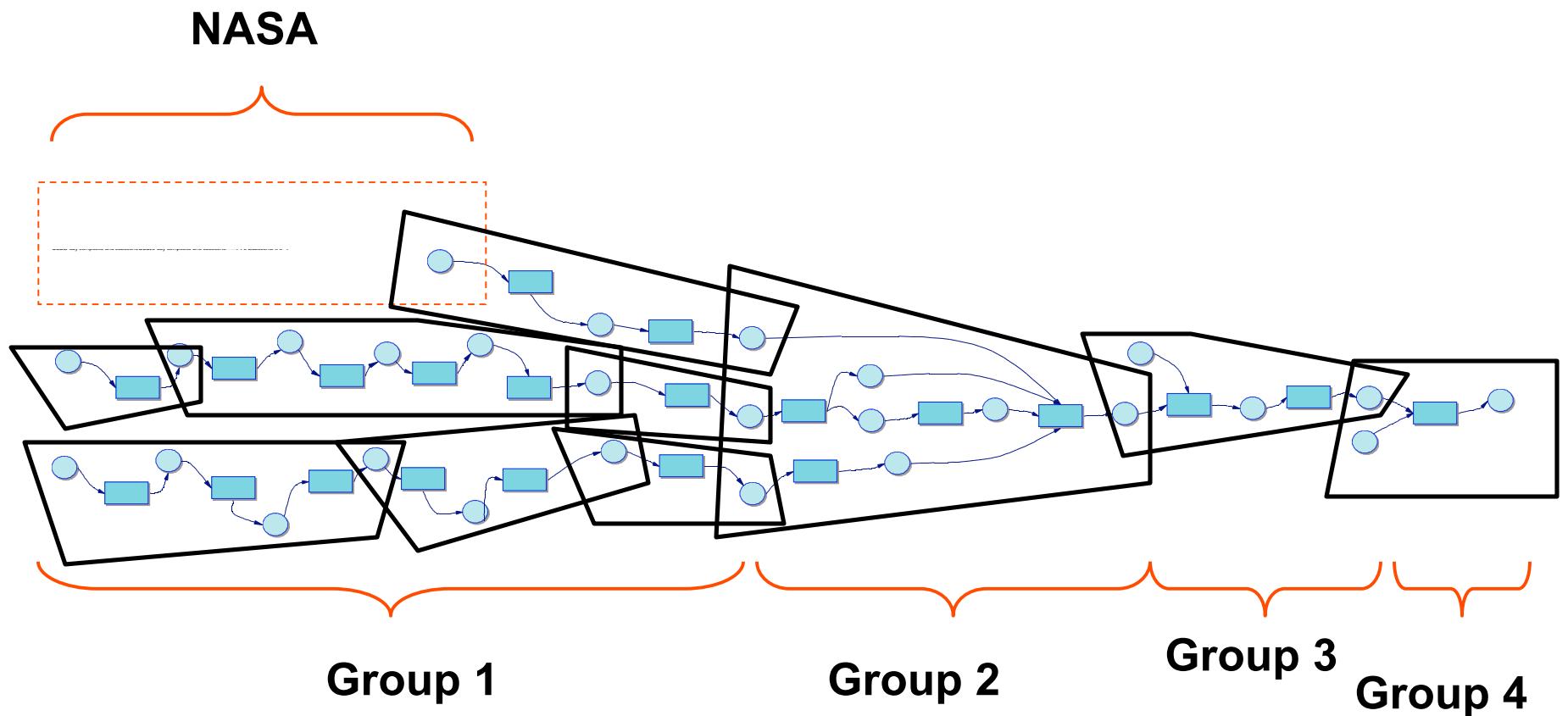


Graph by WebDot

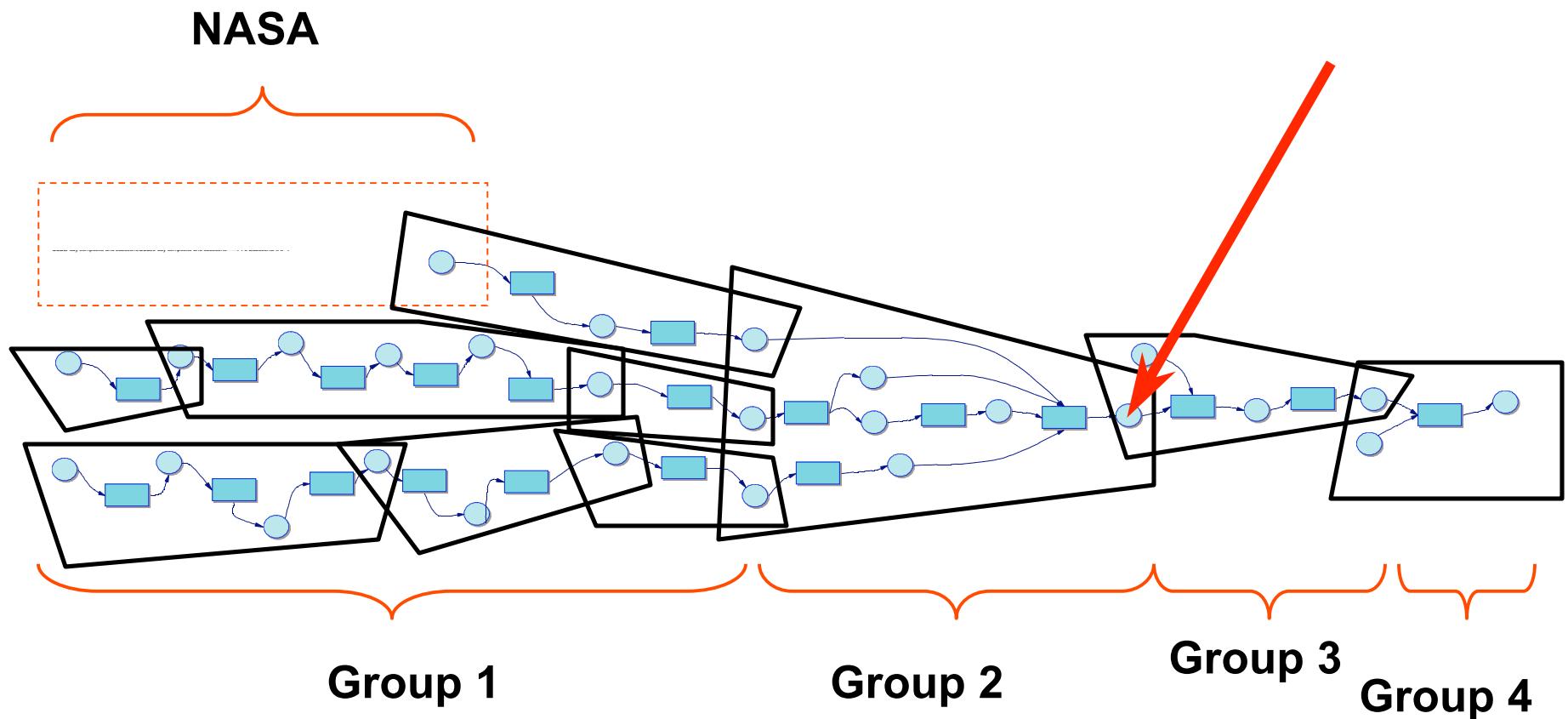
Conveying Lineage Metadata



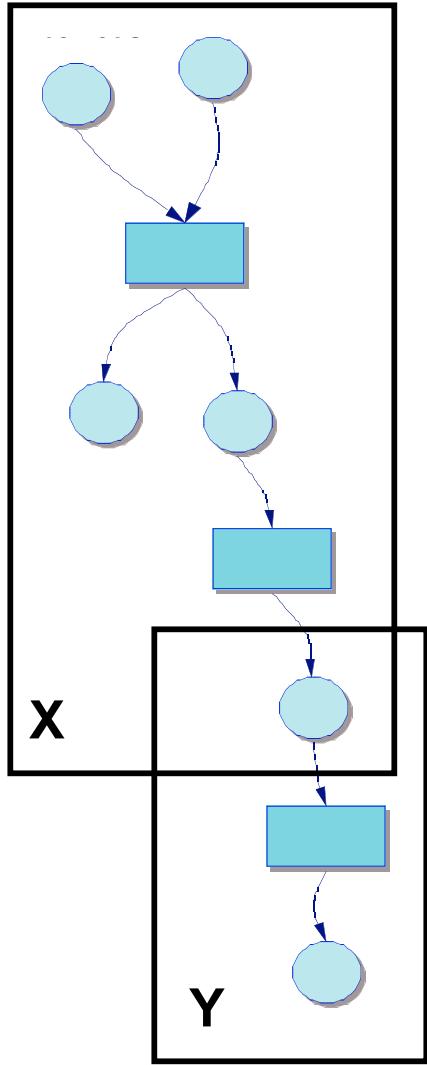
Conveying Lineage Metadata



Conveying Lineage Metadata



Lineage Metadata: RDF Triples



1	inputTo	a
2	inputTo	a
3	createdBy	a
4	createdBy	a
4	inputTo	b
5	createdBy	b
5	inputTo	c
6	createdBy	c
3	createdByWFI	X
4	createdByWFI	X
5	createdByWFI	X
5	inputToWFI	Y
6	createdBYWFI	Y
a	usedByWFI	X
b	usedByWFI	X
c	usedByWFI	Y

C:\Documents and Settings\rbose\My Documents\Research\papers\ssdbm_2004\presentation\lineage_md - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address C:\Documents and Settings\rbose\My Documents\Research\papers\ssdbm_2004\presentation\lineage_md_rdf_example\lineage_with_rdf.xml Norton AntiVirus

```
<!-- 2. Data Quality
-->
- <Data_Quality_Information>
  <Logical_Consistency_Report>String</Logical_Consistency_Report>
  <Completeness_Report>String</Completeness_Report>
  - <Lineage>
    - <rdf:RDF xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
      xmlns:eill="http://www.bren.ucsb.edu/student/phd/rbose/eill#"
      xml:base="http://www.bren.ucsb.edu/student/phd/rbose/ocl/rdf_example/">
      - <rdf:Description rdf:about="S20020332002040.L3m_8D.chlor_a.SBchnl.bin_md_.xml">
          <eill:inputToDT rdf:resource="ctot_calc_20030123_000000_md_.xml" />
        </rdf:Description>
      - <rdf:Description rdf:about="S20020332002040.L3m_8D.mcsst.SBchnl.bin_md_.xml">
          <eill:inputToDT rdf:resource="pbopt_calc_20030123_000000_md_.xml" />
        </rdf:Description>
      - <rdf:Description rdf:about="S20020332002040.L3m_8D_PAR.SBchnl_md_.xml">
          <eill:inputToDT rdf:resource="ppeu_calc_20030123_000000_md_.xml" />
        </rdf:Description>
      - <rdf:Description rdf:about="pbopt_calc_20030123_000000_md_.xml">
          <eill:usedInputDP rdf:resource="S20020332002040.L3m_8D.mcsst.SBchnl.bin_md_.xml" />
          <eill:createdDP rdf:resource="af_pbopt_20040121_122429_md_.xml" />
        </rdf:Description>
      </rdf:RDF>
    </Lineage>
  </Data_Quality_Information>
```

NAMESPACE MANAGEMENT

MODster / DODSter

Global Names: Hierarchical

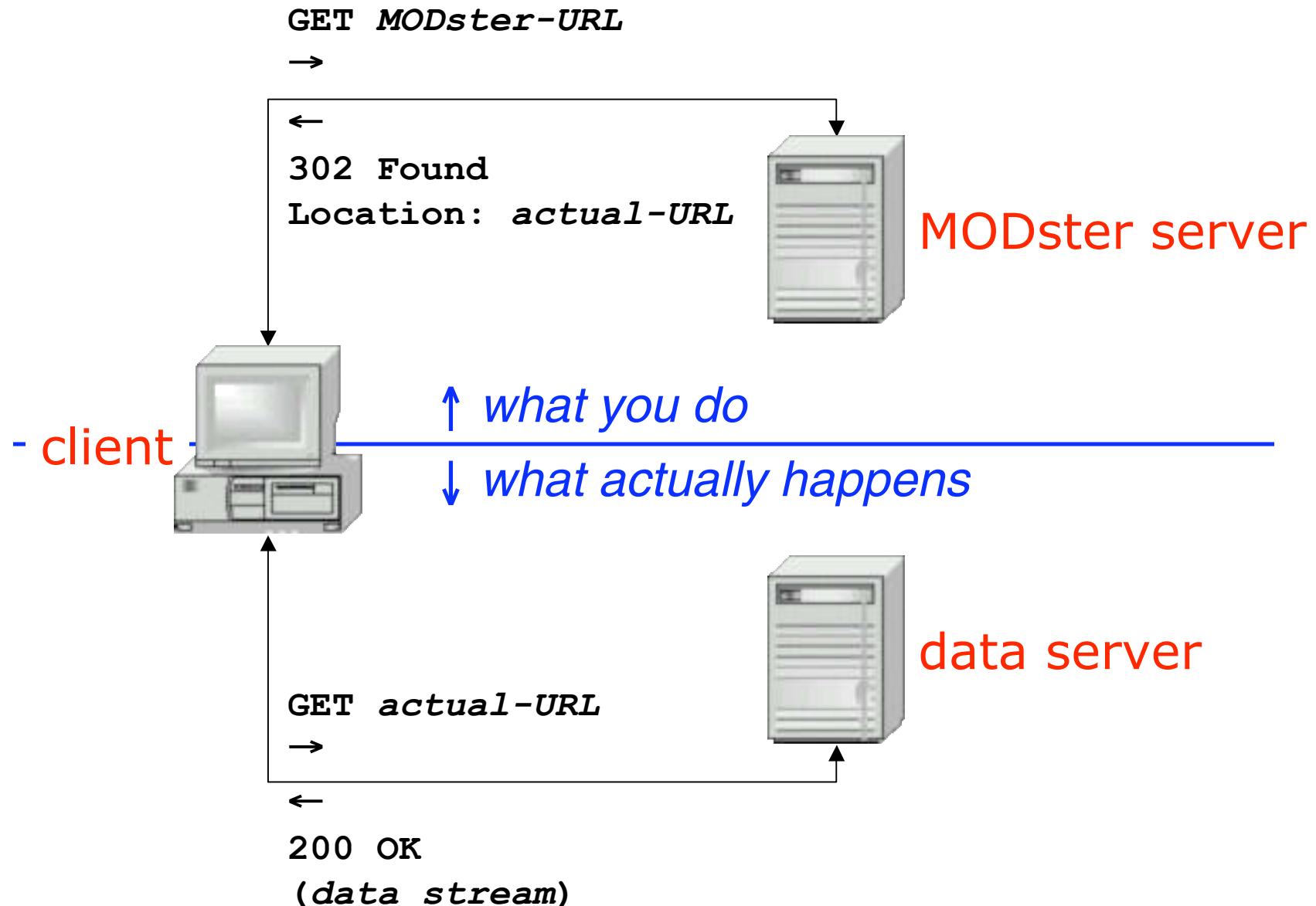
- General form: **server/authority/name**
 - **Server**: interprets names
 - Knows how to contact authority
 - If web server then name is a URL
 - **Authority**: assigns names
 - Must be well-known
 - **Name**: unique within authority
 - Can include any semantics the Authority wants

(based on Kunze's ARK proposal)

Global Name Example: MODster

- ❑ MODIS *granules* have standard names
 - E.g. `MOD03.A2001001.1550.002.2001017185332`
- ❑ Create a NASA global name authority
 - E.g. `MODIS`
- ❑ Set up a global name server
 - E.g. `http://essw.bren.ucsb.edu/modster`
- ❑ Tell name server where MODIS granule lives
- ❑ Name server redirects
 - `http://essw.bren.ucsb.edu/modster/MODIS/MOD03.A2...`
 - to your URL

ADL and MODster



DODS URLs

❑ Parts of a DODS URL

- `http://machine/nph-dods/granule.ext?constraint`
- ext selects type of information returned
 - Values: `das`, `dds`, `info`, `html`, `dods`, `asc`
- constraint modifies data returns (`dods`, `asc`)
 - Select variables or parts of variables
 - E.g.: `x,y,z[10:20]`

❑ Metadata

- `das` and `dds` (for machines)
- `info` (as html)

Using DODSter

- ❑ Combine a MODster URL
with a DODS ext (and maybe also constraint)

MODster URL:

`http://essw ... /modster/MODIS/MOD03.A2hdf`

+ DODS ext for data:

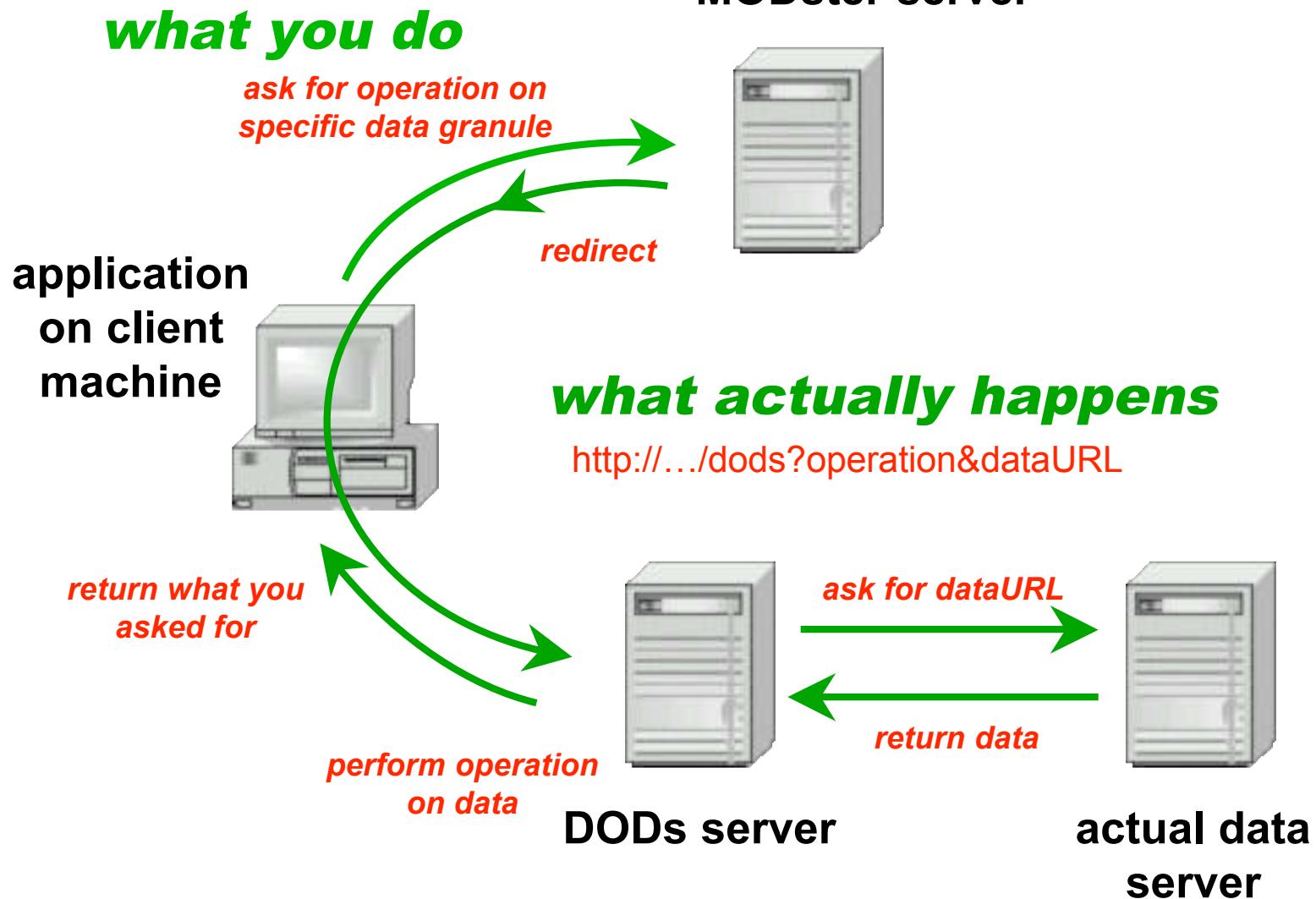
`.dods?SST[1000:1500][525:625]`

= Complete URL:

`http://.../modster/MOD...hdf.dods?SST[1000:1500][525:625]`

Earth System Science Server

http://.../MODIS/data_granule?operation



How DODSter works

- ❑ MODster: who can provide DODS services?
 - DODS-capable MODster sites register themselves as:
 - MODIS/{regular expression}, DODS base URL
 - ◆ MODIS: identifies namespace
 - ◆ {regular ex}: part of namespace this server can handle
 - ◆ DODS Base URL: relevant DODS server

- ❑ DODS: operate on remote data
 - Extend URL syntax to:
`http://.../nph-dods/MODster URL.DODS ext?constraint`
 - e.g.:
`http://.../nph-dods/http://.../modster/MODIS/MODA3... hdf.das`

SEARCH AND EVALUATION

Alexandria Digital Earth Prototype
(ADEPT)

ADEPT: Technology for Digital Libraries

Earth System Science Server

- ❑ Alexandria Digital Earth ProtoType (ADEPT) is:
 - Distributed digital library for geo-referenced information
 - Services supporting DL federation and interoperation
 - Large geospatial collections
- ❑ Distributed, heterogeneous collections
 - Locally, autonomously created and managed
 - Minimal requirements on collection providers
 - allow use of native metadata
- ❑ Uniform client services
 - Common high-level interface across collections
 - Discover / exploit (collection-specific) lower-level interfaces

ADEPT System

❑ Architecture

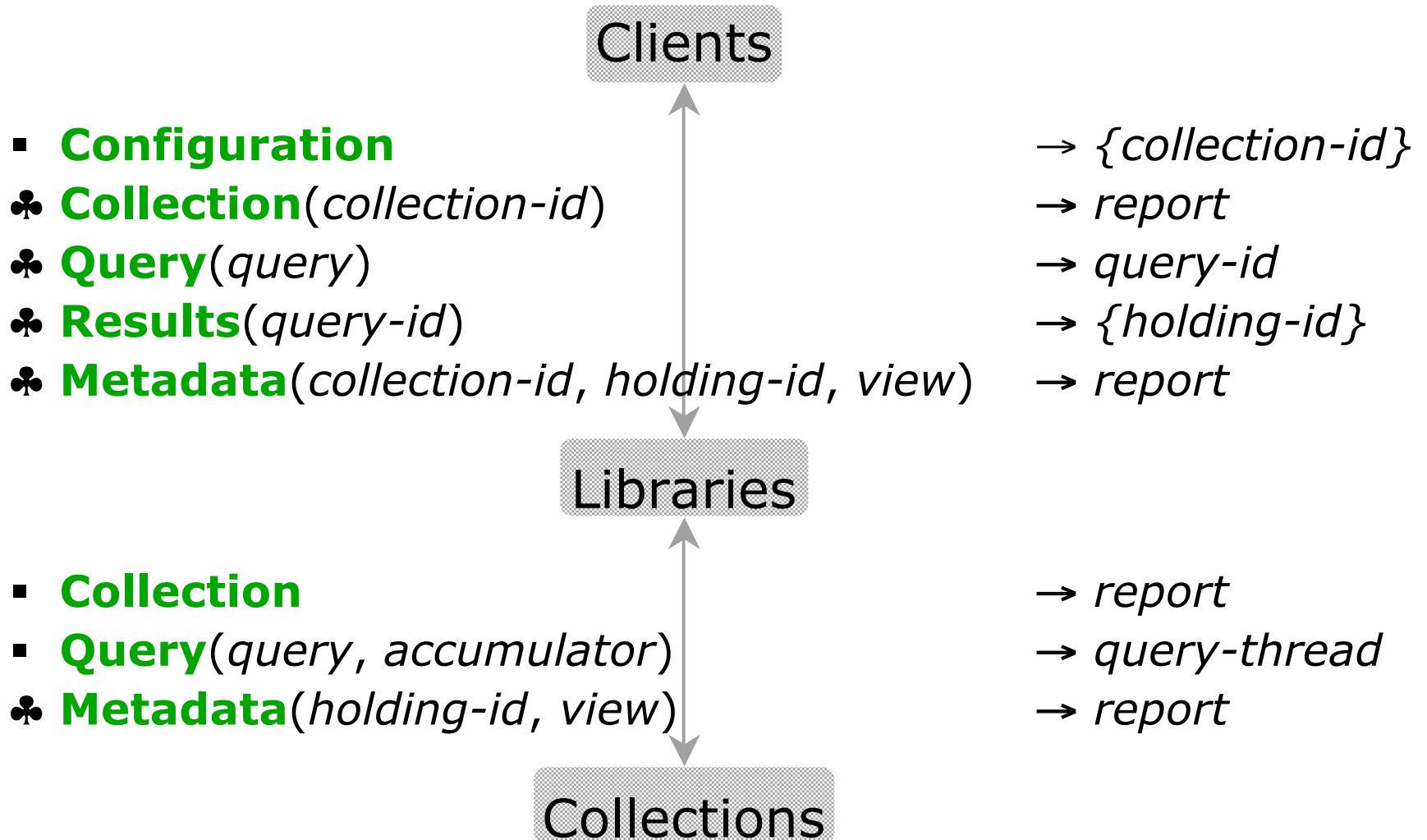
- Item
 - structured descriptions (“reports”)
 - contents (optional)
- Library
 - set of collections
 - client (public) services
- Collection
 - set of items
 - library (internal) services

❑ = distributed catalog system

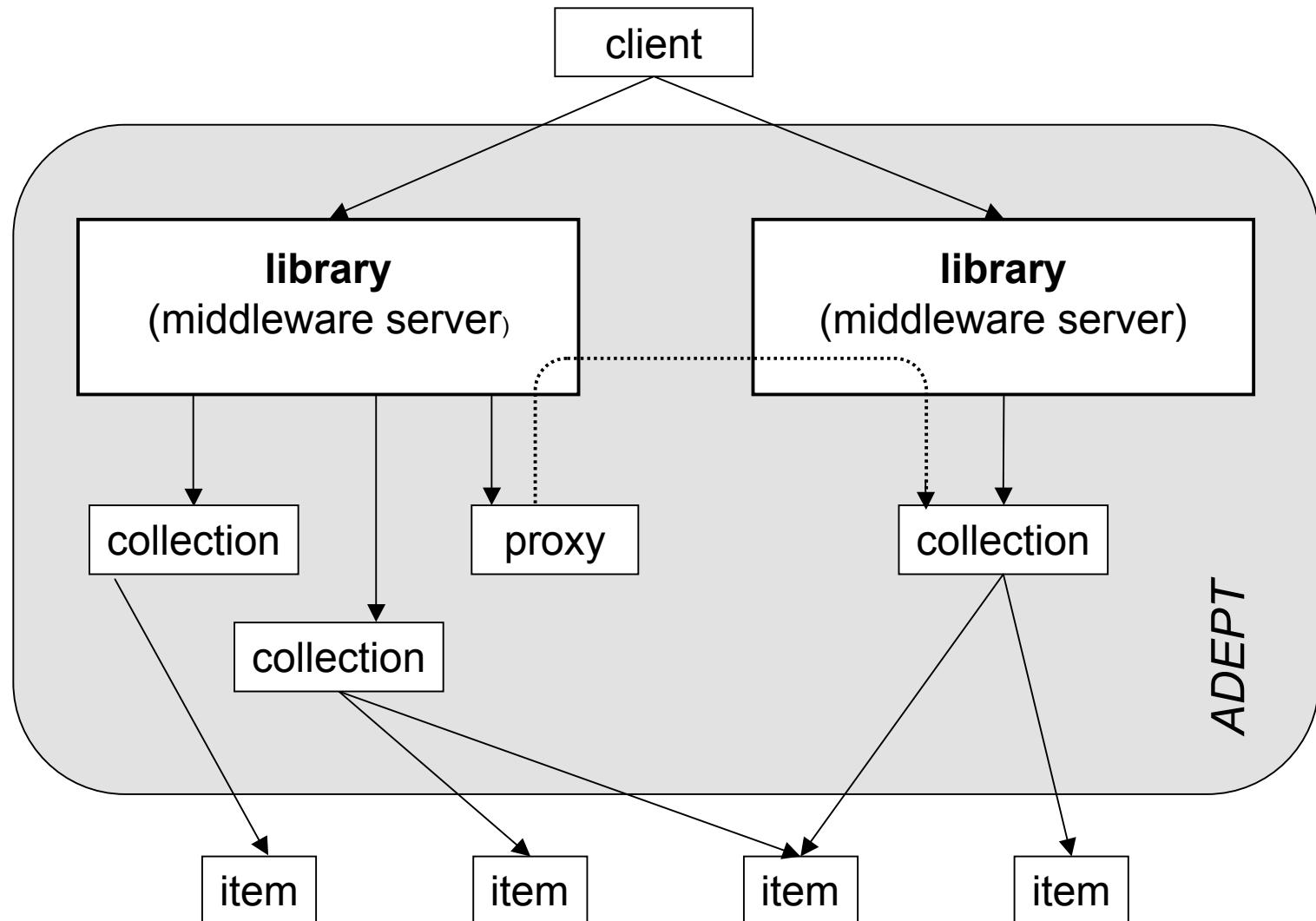
❑ Components

- **Footprints**
 - location(s) ↔ holding
- **Gazetteer**
 - name ↔ footprint
- **HTTP**
 - service ↔ URL(s)
- **Buckets**
 - generic query metadata
- **XML**
 - all visible messages
 - ◆ queries
 - ◆ metadata reports

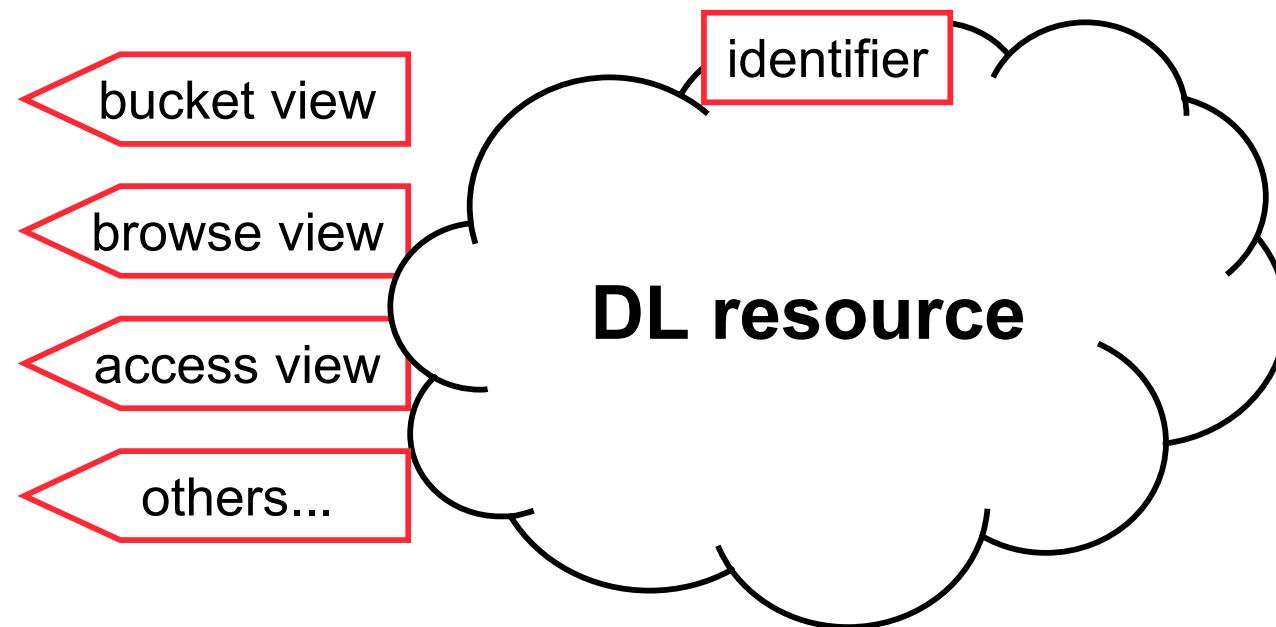
ADEPT Services



The Big Picture



The Little Picture



Metadata Reports

- ❑ Collection
 - Metadata that applies to entire collection
- ❑ Bucket
 - Item's bucket metadata
 - Scan
 - Brief ("1-line") subset of bucket report
- ❑ Full
 - All the item's metadata, in whatever format
- ❑ Browse
 - URL(s) → reduced-resolution {graphics,histograms,...}
- ❑ Access
 - URL(s) → {content,services,...} (if available)

ADEPT “Bucket” Concept

- ❑ Abstract metadata category
 - Strongly typed
 - Defined search semantics
 - query terms
 - defines query operators
 - Explicitly mapped from source metadata
 - e.g.: (FGDC, 1.3, Time period of content, 2001-09-08)
- ❑ Bucket-level search
 - uniform across all collections
 - search all collections for items whose *Originator* bucket contains the phrase “geological survey”

ADEPT “Core” Buckets

- ❑ Subject-related text (textual)
 - Title
 - Assigned term
- ❑ Originator (textual)
- ❑ Geographic location (spatial)
- ❑ Coverage date (temporal)
- ❑ Object type (hierarchical)
- ❑ Feature type (hierarchical)
- ❑ Format (hierarchical)
- ❑ Identifier (qualified textual)

ADL access framework

- ❑ “Access point”
 - a single, independently accessible representation of the resource or subcomponent of the resource
 - four types

- ❑ Hierarchy mechanisms
 - Decomposition (multipart)
 - Alternatives
 - multiple equivalent formats
 - individual components vs. single aggregate
 - ◆ NB: hierarchy mechanisms nest

Types of access points

- ❑ **Download**
 - URL; format, MIME type, encodings, size
- ❑ **Service**
 - URL; protocol, definition
- ❑ **Web interface**
 - URL
- ❑ **Offline**
 - reference or citation

Example

- ❑ U.S. Geological Survey “Digital Raster Graphic”
(scanned topographic map)
 - multiple components (files)
 - image
 - Metadata
 - multiple download options
 - TIFF
 - MrSID (hierarchical multiresolution)
 - multiple offline locations
 - depository libraries

Earth System Science Server

ADEPT Web Client

The screenshot displays the ADEPT Web Client interface. On the left, there is a sidebar with various search filters and parameters:

- SEARCH**: Includes links to "ALEXANDER DIGITAL LIBRARY" and "CAT FINDER DIGITAL LIBRARY".
- SEARCH THE ENTIRE WORLD FOR...**: A search bar with a "Search" button.
- GENERAL SEARCH**:
 - Select collection to search**: Set to "ADL Catalog".
 - Set geographic region**: A map showing California with a green rectangle indicating the search area. Below it is a coordinate box: N 37.00, W 123.00, E 116.00, S 36.00.
 - Words to search for**: Options include "Any of the above words", "All of the above words", and "Exact phrase".
 - Select resource type**: Set to "remote-sensing images (2,014,790)".
 - Select resource format**: Set to "Online (1,034)".
 - Select ranking method**: Set to "None".
 - Select maximum results**: Set to "10".
- Comments**: A text input field for sending comments.

In the center, there is a **Map Browser** window showing a map of California with a green rectangle highlighting a specific area. It includes zoom controls and a "Change location" input field.

On the right, the **ADL Search Results** window shows 17 results. Each result is a numbered list item with a link to a detailed description page. The results are as follows:

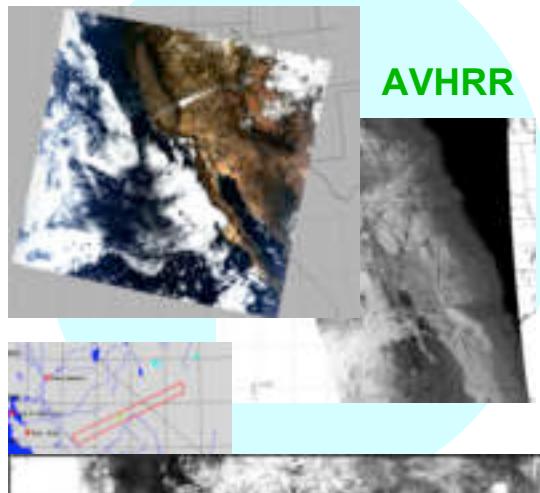
- SPOTView 30 minute x 35 minute [format version 1.5], scene id 2_536279_930501_186845_2P, [mosaicked satellite image of area in California, 30 Minutes x 35 Minutes topographic quadrangle]. Type: remote-sensing images. Format: BIL. Date: May 1, 1993. ADL Identifier: adl_catalog/5000074. HIGHLIGHT IN MAP | COMPLETE DESCRIPTION | BROWSE GRAPHIC | ACCESS/DOWNLOAD
- SPOTView 30 minute (format version 1.5), scene id 2_536279_930707_190940_2P, [mosaicked satellite image of area in California, 30 Minutes topographic quadrangle]. Type: remote-sensing images. Format: BIL. Date: July 7, 1993. ADL Identifier: adl_catalog/5000076. HIGHLIGHT IN MAP | COMPLETE DESCRIPTION | BROWSE GRAPHIC | ACCESS/DOWNLOAD
- SPOTView 37 minute 30 second x 45 minute [format version 1.5], scene id 2_536280_931221_185641_2P, [mosaicked satellite image of area in California, 37 Minutes 30 Seconds x 45 topographic quadrangle]. Type: remote-sensing images. Format: BIL. Date: December 21, 1993. ADL Identifier: adl_catalog/5000077. HIGHLIGHT IN MAP | COMPLETE DESCRIPTION | BROWSE GRAPHIC | ACCESS/DOWNLOAD
- SPOTView 30 minute (format version 1.5), scene id 2_537279_930426_186401_1P, [mosaicked satellite image of area in California, 30 Minutes topographic quadrangle]. Type: remote-sensing images. Format: BIL. Date: April 26, 1993. ADL Identifier: adl_catalog/5000082. HIGHLIGHT IN MAP | COMPLETE DESCRIPTION | BROWSE GRAPHIC | ACCESS/DOWNLOAD
- SPOTView 37 minute 30 second x 30 minute [format version 1.5], scene id 2_537280_930426_185500_1P, [mosaicked satellite image of area in California, 37 Minutes 30 Seconds x 30 topographic quadrangle]. Type: remote-sensing images. Format: BIL. Date: April 26, 1993. ADL Identifier: adl_catalog/5000083. HIGHLIGHT IN MAP | COMPLETE DESCRIPTION | BROWSE GRAPHIC | ACCESS/DOWNLOAD
- SPOTView 15 minute x 35 minute (format version 1.5), scene id 2_537282_930426_185517_1P, [mosaicked satellite image of area in California, 15 Minutes x 35 Minutes topographic quadrangle]. Type: remote-sensing images. Format: BIL. Date: April 26, 1993. ADL Identifier: adl_catalog/5000084. HIGHLIGHT IN MAP | COMPLETE DESCRIPTION | BROWSE GRAPHIC | ACCESS/DOWNLOAD
- SPOTView 30 minute (format version 1.5), scene id 2_538279_930501_186841_1P, [mosaicked satellite image of area in California, 30 Minutes topographic quadrangle]. Type: remote-sensing images. Format: BIL. Date: May 1, 1993. ADL Identifier: adl_catalog/5000085. HIGHLIGHT IN MAP | COMPLETE DESCRIPTION | BROWSE GRAPHIC | ACCESS/DOWNLOAD

ESSW data lineage tracking

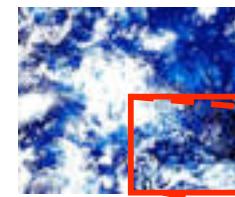
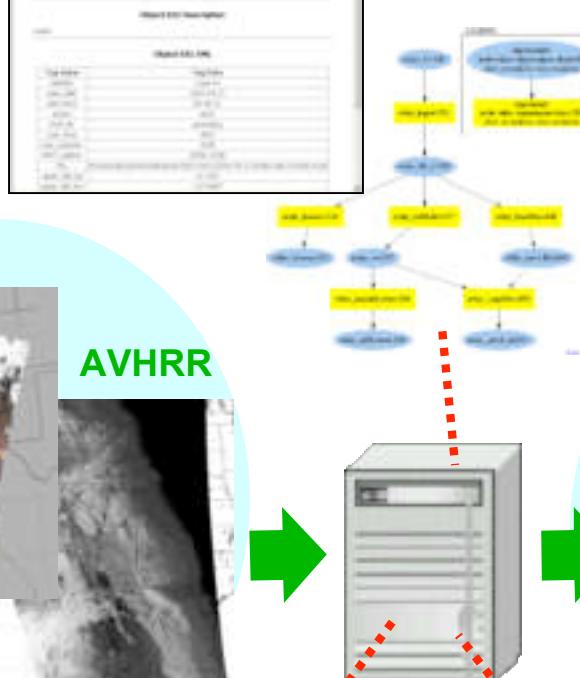
ES³ : Earth System Science Server



MODIS

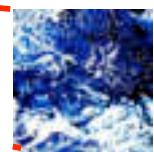


AVHRR

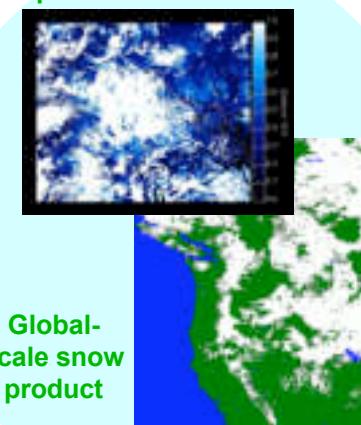


MODster

OpenDAP



Watershed-scale snow product

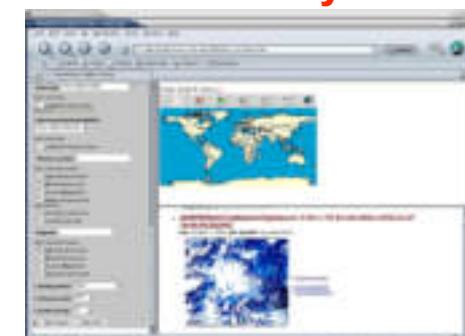


Microsoft TerraServer

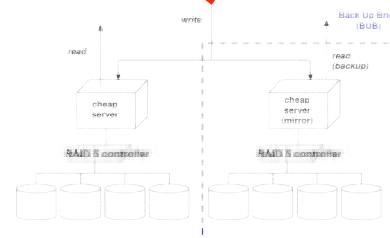


Global-scale snow product

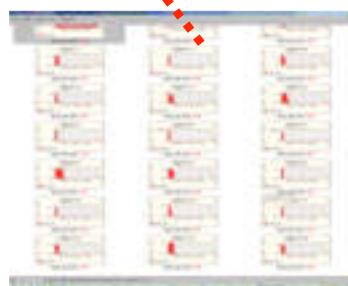
Alexandria Digital Library



Corona



BUB data storage



ROCKS processing clusters